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Indian Standard

METHOD OF TEST FOR COEFFICIENTS OF FRICTION OF PLASTIC FILM AND SHEETING FOR USE AS ELECTRICAL INSULATION

UDC 621·315·616·9-416 : 620·178·162

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(*Page* 11, *clause* **8.4**) — Substitute the following for the existing formula:

$$S = \sqrt{\frac{\Sigma(X)^2 - n(\overline{X})^2]}{n-1}}$$

(ETDC 63)

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Indian Standard

METHOD OF TEST FOR COEFFICIENTS OF FRICTION OF PLASTIC FILM AND SHEETING FOR USE AS ELECTRICAL INSULATION

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METHOD OF
TEST FOR COEFFICIENTS OF FRICTION OF PLASTIC FILM AND SHEETING FOR USE AS ELECTRICAL INSULATION

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 25 June 1986, after the draft finalized by the Solid Electrical Insulating Materials Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This method covers determination of the coefficients of starting and sliding friction of plastic film and sheeting when sliding over itself or other substances under specified test conditions.

0.2.1 Measurements of frictional properties may be made on a film or sheeting specimen when sliding over itself or over another substance. The coefficients of friction are related to the slip properties of plastic films that are of wide interest in electrical insulation applications. These methods yield empirical data for control purposes in film production. Correlation of test results with actual performance can usually be established.

0.2.2 Slip properties are generated by additives in some plastic films, for example, polyethylene. These additives have varying degrees of compatibility with the film matrix. Some of them bloom or exude to the surface, lubricating it and making it more slippery. Because this blooming action may not always be uniform on all areas of the film surface, values from these tests may be limited in reproducibility.

0.2.3 The frictional properties of plastic film and sheeting may be dependent on the uniformity of the rate of motion between the two surfaces. Care should be exercised to ensure that the rate of motion of the equipment is as carefully controlled as possible.

0.2.4 Data obtained by these procedures may be extremely sensitive to the age of the film or sheet and the condition of the surfaces. The blooming action of many slip additives is time-dependent. For this reason, it is sometimes meaningless to compare slip and friction properties of films or sheets produced at different times, unless it is desired to study this effect.

0.2.5 Frictional and slip properties of plastic film and sheeting are based on measurements of surface phenomena. Where products have been made by different processes, or even on different machines by the same process, their surface may be dependent on the equipment or its running conditions. Such factors must be weighed in evaluating data from these methods,

0.2.6 The measurement of the static coefficient of friction is highly dependent on the rate of loading and on the amount of blocking occurring between the loaded sled and the platform due to variation in time before motion is initiated.

0.2.7 Care should be exercised to make certain that the speed of response of the recorder, either electronic or mechanical, is not exceeded.

0.3 Specifications for plastic films for electrical purposes are covered by IS : 11298.

0.4 In the preparation of this standard, assistance has been derived from IEC Pub 648-1979 'Method of test for coefficients of friction of plastic film and sheeting for use as electrical insulation', issued by the International Electrotechnical Commission.

0.5 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This method covers determination of the coefficients of starting and sliding friction of plastic film and sheeting when sliding over itself or other substances under specified test conditions. The coefficient of friction values for a given sample will yield the same values by the use of a stationary sled with a moving plane or a moving sled with a stationary plane.

2. TERMINOLOGY

2.1 Slip — A term denoting lubricity of two surfaces sliding in contact with each other. In a sense, it is the antithesis of friction in that high coefficient of friction denotes low slip and low coefficient of friction high slip.

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*Rules for rounding off numerical values (*revised*).

2.2 Friction — The resisting force that arises when a surface of one substance slides or tends to slide over an adjoining surface of itself or another substance. Between surfaces of solids in contact there may be two kinds of friction:

a) the resistance opposing the force required to start to move one surface over another, and

b) the resistance opposing the force required to move one surface over another at a variable, fixed or predetermined speed.

2.3 Coefficient of Friction — The ratio of the frictional force, defined in **2.2,** to the force, usually gravitational, acting perpendicular to the two surfaces in contact. This coefficient is a measure of the relative difficulty with which the surface of one material will slide over an adjoining surface of itself, or of another material.

2.3.1 The static or starting coefficient of friction (μ_s) is related to the force measured to begin movement of the surfaces relative to each other. The kinetic or sliding coefficient of friction (μ_k) is related to the force measured in sustaining this movement.

3. TEST SPECIMENS

3.1 Five specimens shall be tested for each sample, unless otherwise specified.

3.2 The test specimen that is to be attached to the plane shall be cut approximately 250 mm in the machine direction and 130 mm in the transverse direction when such extrusion directions exist and are identifiable.

3.3 A film specimen having a nominal thickness of not greater than 0·254 mm that is to be attached to the sled shall be cut approximately 120 mm square.

3.4 A plastic sheeting specimen (greater than 0·254 mm nominal thickness) or another substance that is to be attached to the sled shall be cut 63·5 mm square.

3.5 Plastic sheeting specimens shall be flat and free of warpage. Edges of specimens shall be rounded smooth.

NOTE 1 — Plastic films and sheeting may exhibit different frictional properties in their respective principal directions due to anisotropy or extrusion effects. Specimens may be tested with their long dimension in either the machine or transverse direction of the sample, but is more common practice to test the specimen as described in **3.2**, with its long dimension parallel to the machine direction.

NOTE 2 — *Caution* — Extreme care must be taken in handling the specimens. The test surface must be kept free of all dust, lint, finger-points, or any foreign matter that might change the surface characteristics of the specimens.

4. CONDITIONS

4.1 Conditioning — Condition the test specimens at 27 ± 2°C and 60 ± 5 percent relative humidity for not less than 40 h prior to test, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be ± 1°C and ± 2 percent relative humidity.

4.2 Test Conditions — Conduct tests in the standard laboratory atmosphere of 27 ± 2°C and 60 ± 5 percent relative humidity, unless otherwise specified in this report. In cases of disagreement, the tolerences shall be ± 1°C and ± 2 percent relative humidity. In specific cases, such as control testing, where the conditioning requirements cannot be met and the data still may be of direct assistance to the operation, other conditioning procedures may be used and recorded in the test report. Frictional properties should be measured only after sufficient time has been allowed for the specimens to reach essential equilibrium with the ambient atmosphere.

5. APPARATUS

5.1 Sled — A metal block 63·5 mm square by approximately 6 mm thick with a suitable eye screw fastened in one end. When flexible film (*see* **3.3**) is to be attached, the block shall be wrapped with 3·2 mm thick medium density foam rubber. The rubber shall be wrapped snugly around the sled end-to-end and fastened in position. When a plastic sheet (**3.4**) is to be attached, double-faced tape shall be used to attach the specimen. The total mass of the (wrapped) sled and specimen should be 200 ± 5 g.

5.2 Plane — A polished plastic, wood or metal sheet, approximately 150 × 1 mm. A smooth, flat piece of glass may cover the upper surface of the plane. This provides a smooth support for the specimen.

5.3 Scissors or cutter suitable for cutting specimens to the desired dimensions.

5.4 Adhesive tape, cellophane or pressure-sensitive, single-faced.

5.5 Adhesive tape, double-faced.

5.6 Nylon monofilament, having a 0·33 ± 0·05 mm diameter and capable of supporting a 3·6 kg load.

5.7 Low Friction Pulleys — A phenolic type pulley mounted in hardened steel cone bearings on a metal fork. A ball-bearing type pulley may also be used.

5.8 Force-Measuring Device — Capable of measuring the factional force to ± 5 percent of its value. A spring gauge (*see* Note) universal testing machine, or strain gauge may be used.

NOTE — The capacity of the spring gauge (Fig. 1A and 1B) needed will depend upon the range of values to be measured. For most plastics, a 500 g capacity gauge with 10 g of smaller subdivisions will be satisfactory. This spring will measure coefficients of friction up to and including 2·5.

5.9 Supporting Base — A smooth wood or metal base approximately 200 × 380 mm is necessary to support the plane. The supporting base may be a simple rectangular box. If a universal testing machine is used to pull a moving plane, a supporting base of sufficient structural strength and rigidly to maintain a firm position between the moving crosshead and the force-measuring device will be necessary.

5.10 Driving or Pulling Device for Sled or Plane — The plane may be pulled by a driven pair of rubber-coated rolls not less than 200 mm long, capable of maintaining a uniform surface speed 150 ± 30 mm/min (Fig. 1B) by the crosshead of a universal testing machine (Fig. 1D and Note) or a worm drive driven with a synchronous motor (Fig. 1E) A constant speed chain-drive system has also been found satisfactory (Fig. 1A). A power-operated source may be used for pulling the sled over the horizontally mounted specimen at a uniform speed of 150 ± 30 mm/min. A universal testing machine equipped with a load cell in its upper crosshead and a constant rate-of-motion lower crosshead has been found satisfactory (*see* Fig. 1C).

NOTE — Where the moving crosshead of a universal testing machine is used to pull the moving plane through a pulley system (Fig. 1D), the strain gauge load cell, or other load-sending instrument in the testing machine, acts as the force-measuring device.

6. SELECTION OF APPARATUS

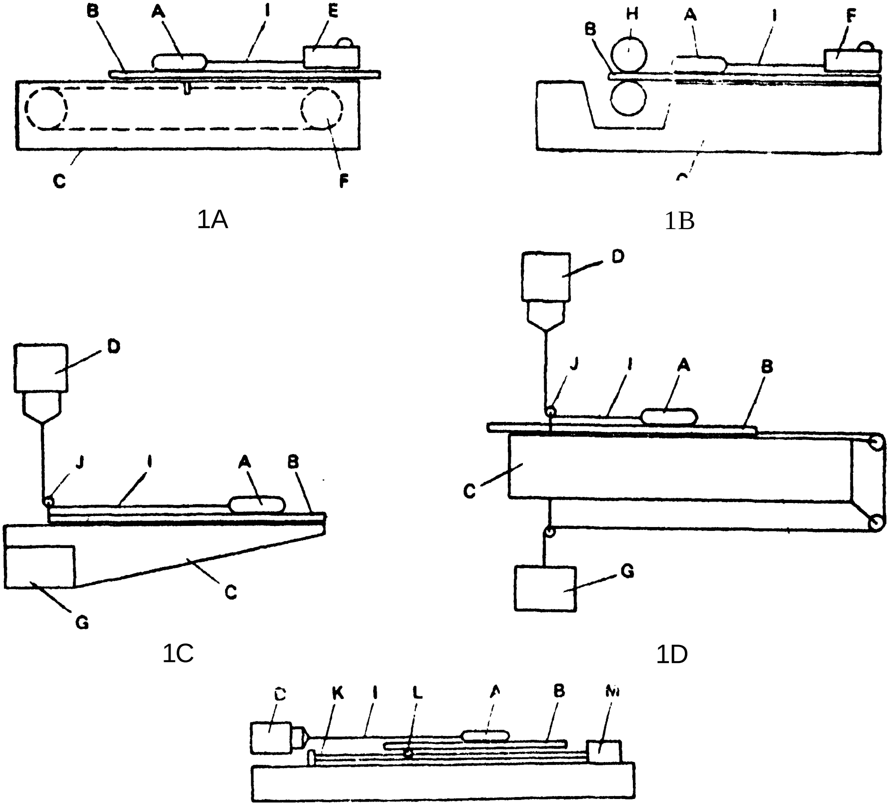
6.1 Figures 1A to 1E show five ways in which the apparatus may be assembled. The support bases for all apparatus assemblies shall be level.

6.2 If the apparatus of Fig. 1A or 1B is used, calibrate the scale of the spring gauge as follows.

6.2.1 Mount the low friction pulley in front of the spring gauge.

6.2.2 Fasten one end of the nylon filament to the spring gauge, bring the filament over the pulley and suspend a known weight on the lower end of the filament to act downward.

NOTE — The reading on the scale shall correspond to the known mass within ± 5 percent. The weight used for this calibration shall be between 50 percent and 75 percent of the scale range on the gauge.



1A

1B

1C

1D

1E

A = Sled
B = Plane
C = Supporting base
D = Strain gauge
E = Spring gauge
F = Constant-speed chain drive
G = Constant-speed tensile tester crosshead
H = Constant-speed drive rolls
I = Nylon monofilament
J = Low-friction pulley
K = Worm screw
L = Half nut
M = Hyeteresis, synchronous motor

FIG. 1 FIVE METHODS OP ASSEMBLY OF APPARATUS FOR DETERMINATION OF COEFFICIENTS OF FRICTION OF PLASTIC FILMS

6.3 The drive speed for the apparatus of Fig. 1A and 1B shall be adjusted to 150 ± 30 mm/min. This speed may be checked by marking off a 150 mm section beside the plane and determining the time required for the plane to travel 150 mm.

6.4 If the apparatus of Fig. 1C and 1D employing a universal testing machine is used, select the proper speed setting for a crosshead motion of 150 ± 30 mm/min. A similar speed for the load displacement recorder is desirable. However, the speed of the recorder can be adjusted to give the desired accuracy in reading the pen trace.

6.5 When the apparatus of Fig. 1C (moving sled/stationary plane) is used, wipe the support base free of foreign matter and lay down two strips of double-faced adhesive tape along the length of the supporting base so that there is approximately 100 mm between the centres of the strips.

6.6 Fix the plane in position on the tape strips and firmly press in place.

7. PROCEDURE

7.1 Tape the 250 × 130 mm film or sheet specimen to the plane with the machine direction of the specimen in the 250 mm direction. Smooth the film specimen to eliminate wrinkles, if necessary, taking care not to alter the specimen through finger oils, etc.

NOTE 1 — For some samples, it has been found necessary to tape only the leading edge of the specimen to the plane. In some cases, the specimen has been pulled through the nip rolls apparatus of Fig. 1B without the plane. However, should any dispute arise, taping of all four edges will be the referee method.

NOTE 2 — For the sake of uniformity and later comparison when testing a specimen sliding over itself, the specimens shall be mounted so that the same side of the specimen shall be used as the contact surface for both the moving and stationary specimens.

NOTE 3 — Coefficient of friction measurements may be made on a film or sheeting specimen when sliding over itself or over other substance surfaces wherein the movement is made in the transverse direction of the specimen. However, the methods described here will be confined to movements in the machine direction of the specimens.

7.2 For film specimens, tape the edges of the 120 mm^2 film specimen to the back of the sled, using adhesive tape and pulling the specimen tight to eliminate wrinkles without stretching it. For sheet specimens, tape the 63·5 mm^2 sheet specimen or second substrate to the sled face with double-faced tape. Keep the machine direction of the specimen or second substrate to the sled face with double-faced tape. Keep the machine direction of the specimen parallel to the length of the sled (where such a direction exists and is identifiable).

7.3 Attach the specimen-covered sled through its eye screw to the nylon filament. If a universal testing machine if used (Fig. 1C and 1D), pass the filament through pulley(s) and upward to the bottom of the load sensing device and attach securely. If a spring gauge is used (Fig. 1A and 1B), securely attach the filament to it. The nylon filament shall be of sufficient length to allow maximum sled or plane travel. With some slack in the nylon filament, lightly place the sled in position on the horizontal place (*see* Note).

The positioning of the sled shall be such that the length of the sled, the adjacent length of nylon filament and the long dimension (machine direction) of the plane mounted specimen are parallel.

NOTE — The sled must be placed very lightly and gently on the plane to prevent any unnatural bond from developing. A high-starting coefficient of friction may be caused by undue pressure on the sled when mounting it onto the plane.

7.4 Start the driving mechanism (which has been adjusted previously) to provide a speed of 150 ± 30 mm/min. As a result of the frictional force between the contacting surfaces, no immediate relative motion may take place between the sled and the moving plane until the pull on the sled is equal to, or exceeds, the static frictional force acting at the contact surfaces. Record this initial maximum reading as the force component of the static coefficient of friction.

7.5 Record the visual average reading during a run of approximately 130 mm while the surfaces are sliding uniformly over one another. This is equivalent to the kinetic force required to sustain motion between the surfaces and normally is lower than the static force required to initiate motion. After the sled has travelled over 130 mm, stop the apparatus and return to the starting position.

7.6 If a strain gauge and load displacement recorder are used, either draw the best straight line midway between the maximum points and minimum points shown on the chart while the sled was in motion, or obtain the average load by integration of the recorder trace. The mean load is the kinetic friction force required to sustain motion on the sled.

7.7 Remove the film or sheeting specimen from the sled and the horizontal plain. The apparatus is now ready for the next set of specimens. A new set of specimens shall be used for each run. No specimen surface(s) shall be tested more than once unless such testes constitute one of the variables to be studied.

NOTE — The maximum point at which initial motion takes place between the sled and the horizontal plane should be carefully examined with reference to the rate of loading and the speed of response of the sensing device. Failure to consider this factor can lead to meaningless results for the value of the static coefficient of friction.

8. RESULTS

8.1 Calculate the static coefficient of friction μ_s, as follows:

$$\mu_s = \frac{A_s}{B}$$

where

A_s = initial motion scale reading, in grams; and

B = mass of sled, in grams.

B.2 Calculate the kinetic coefficient of friction μ_k, as follows:

$$\mu_k = \frac{A_k}{B}$$

where

A_k = average scale reading obtained during uniform sliding of the film surfaces, in grams; and

B = mass of sled, in grams.

8.3 Calculate the arithmetic mean of each set of observations and report these values to three significant figures.

8.4 Calculate the standard deviation (estimated to be ± 15 percent of the value of the coefficient of friction) as follows, and report it to two significant figures:

$$S = \sqrt{\frac{(\Sigma X^2 - nX^2)}{n - 1}}$$

where

S = sample standard deviation,

X = value of single observation,

n = number of observations, and

$\bar{X}$ = arithmetic mean of the set of observations.

9. REPORT

9.1 The report shall include the following.

9.1.1 Complete description of the plastic sample, including manufacturer's code designation, thickness, method of production, surfaces tested, principal directions tested, and approximate age of sample after manufacture.

9.1.2 Description of second substance, if used.

9.1.3 Apparatus used.

9.1.4 Average static and kinetic coefficients of friction, together with the standard deviation.

9.1.5 Number of specimens tested for each coefficient of friction.

INTERNATIONAL SYSTEM OF UNITS (SI UNITS)

Base Units

QUANTITY	UNIT	SYMBOL
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Luminous intensity	candela	cd
Amount of substance	mole	mol

Supplementary Units

QUANTITY	UNIT	SYMBOL
Plane angle	radian	rad
Solid angle	steradian	sr

Derived Units

QUANTITY	UNIT	SYMBOL	DEFINITION
Force	newton	N	1 N = 1 kg.m/s^2
Energy	joule	J	1 J = l N.m
Power	watt	W	I W = 1 J/s
Flux	weber	Wb	1 Wb = 1 V.s
Flux density	tesla	T	1 T = 1 Wb/m^2
Frequency	hertz	Hz	1 Hz = 1 c/s (s^{-1})
Electric conductance	siemens	S	1 S = 1 A/V
Electromotive force	volt	V	1 V = 1 W/A
Pressure, stress	pascal	Pa	1 Pa = 1 N/m^2

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